METEOROLOGICAL\CCAFS\81900\CLOUD TO GROUND LIGHTNING SURVEILLANCE SYSTEM (CGLSS)

Information last updated: January 2002

Station: CCAFS

Facility: 81900 (Range Operations Control Center (ROCC))

External Interfaces:

1. One way to AMU, ROCC, CCAFS
2. One way to LDAR at NASA, KSC
3. One way to MIDDS, ROCC, CCAFS

1.0 SYSTEM DESCRIPTION

The Cloud to Ground Lightning Surveillance System (CGLSS) is a lightning detection system designed to record cloud-to-ground lightning strikes in the vicinity of KSC and CCAFS. It consists of (6) Global Atmospherics, Inc. (GAI) Model 141-T Advanced Lightning Direction Finders (ALDF), a GAI IMPACT 283-T Advanced Position Analyzer (APA) and Network Display System (NDS) equipment.

- IMPACT stands for IMProved Accuracy from Combined Technology and distinguishes GAI's lightning-detection system using Global Positioning System (GPS) technology.
- The ALDF are located at sites in and around KSC and CCAFS as shown in Figure - 1, and serve as the field sensors for the system. Each ALDF has the capability of independently measuring the relative signal strength and direction to a cloud-to-ground lightning strike. The vendor reports a detection efficiency of 75% within 50 nmi (92.5 km) on the low gain (1) setting.
- The APA is located in Rm. 146.2 of the Range Operations Control Center (ROCC) on CCAFS and is the central data processor for the system.
- The NDS equipment is located in the Range Weather Operations (RWO) of the ROCC and provides the user with a graphical display of the lightning data.

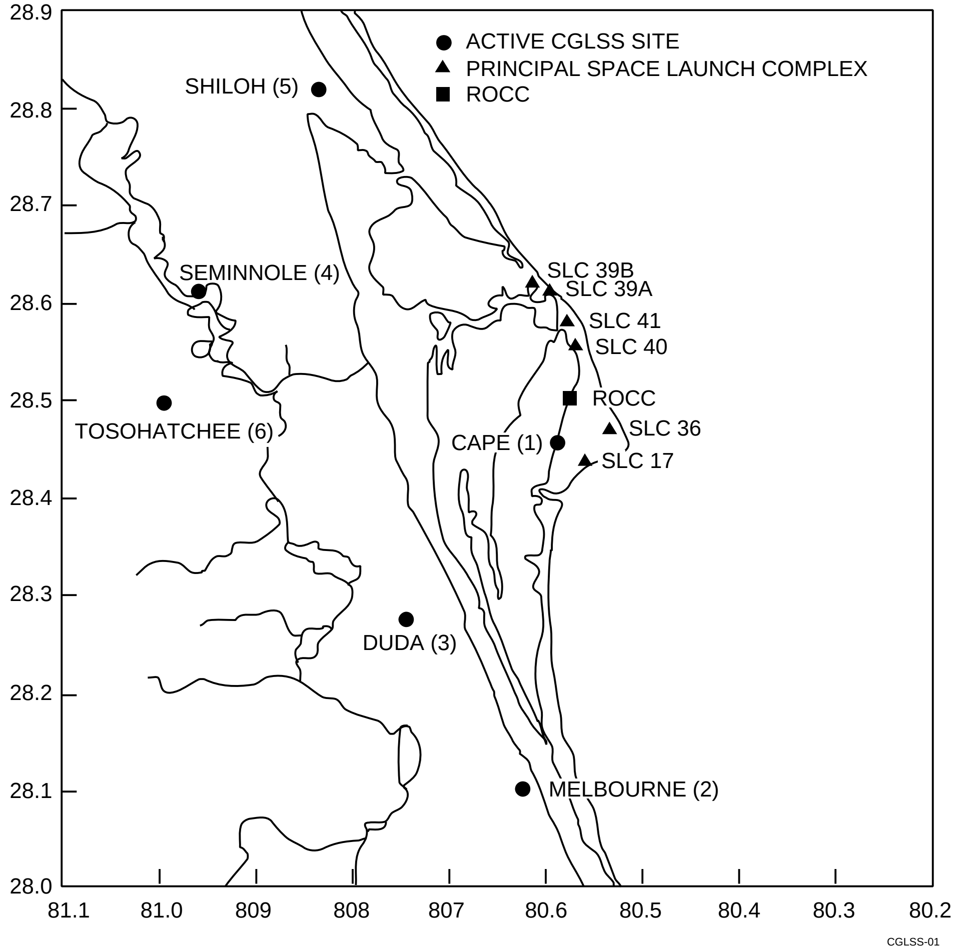

Figure -1. Cloud-To-Ground Lightning Surveillance System (CGLSS) Sensor Locations

There are also one-way links to provide data to the Lightning Detection and Ranging (LDAR) system at NASA KSC, the Applied Meteorology Unit (AMU) at the ROCC and the Meteorological Interactive Data Display System (MIDDS) at the ROCC.

All ALDF sensors and the APA were upgraded in May 1998 to include GPS positioning and timing capability and a new ALDF site was also added at Tosohatchee, Florida.

The ROCC is powered by commercial power from two feeds one from the north and one from the south through the ROCC Uninterruptible Power Supply (UPS). The ROCC UPS has two battery banks (UPS Common 1 and UPS Common 2). All meteorological systems are attached to UPS Common 2. The UPS will power the ROCC for approximately one hour. If generator power were not readily available an orderly shut down of all systems would have to be completed during that one hour period. Now that the ROCC is equipped with generator backup the UPS is required to keep systems operational until the generator is brought on-line. The generator is designed to come on-line within 90 seconds of a power outage.

The six remote sites were upgraded between January and March of 2000, by the RTSC; to include new communications boxes capable of holding the addition of an UPS and surge suppressors added to eliminate problems with power surges. Prior to the upgrade the site modems would hang-up and require a technician to visit a site to clear the problem. With the addition of the UPS a site will remain operational for approximately 25 minutes following loss of commercial power.

1.1 ADVANCED LIGHTNING DIRECTION FINDER (ALDF)

The Model 141-T ALDF sensor consists of an antenna assembly, electronics module and interface enclosure mounted on a support mast anchored to a concrete pad (Figure -2). The antenna assembly consists of two magnetic direction-finding antennas oriented East-West and North-South, three horizontal electric field antenna plates and a GPS antenna on top of the upper electric field antenna plate. The antenna assembly and the electronics module (also called the Primary Line Replacement Unit (PLRU), containing 5 printed circuit boards) are housed inside a weatherproof, dome-shaped enclosure atop the short (107 cm) permanently mounted mast. Total installed height of the operational ALDF is 168 cm with a diameter of 34.3 cm. Mounted on the side of the mast is the Interface Enclosure, also called the Interface Line Replaceable Unit (ILRU), containing the AC power bracket, AD/DC power interface board, communication board, main power board and main power transformer. Power is 120 VAC supplied through the commercial power grid. Communication is via modem over dedicated phone lines. Once an ALDF is installed, configured and aligned, the sensor automatically provides lightning detection and location data to the APA 24 hours a day. Installation, configuration and alignment procedures are covered in the GAI "*IMPACT ALDF Models 141-T and 141 TES Installation, Operation and Maintenance*" manual.

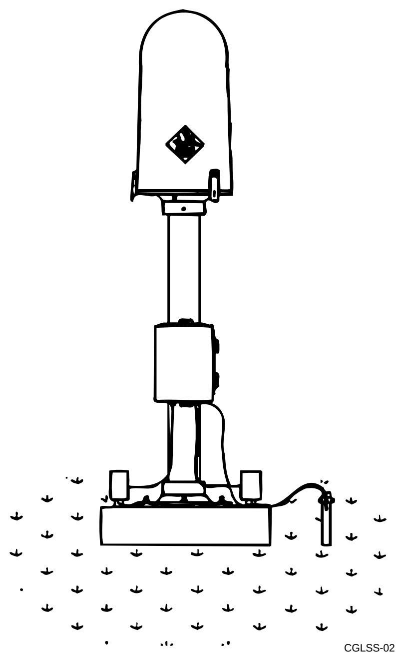

Figure -2. Model 141 Series ALDF Sensor

The ALDF have a “nominal range” of up to 400 nmi on the Extra High Gain (6) setting, but the ALDF at CCAFS/KSC are normally used on the Low Gain (1) setting for increased accuracy (vendor reported nominal range of 50 nmi). Directional accuracy is quoted as better than 1 degree within the nominal range when the magnetic direction-finding antennae are aligned within 0.25 degree of true north. Antenna alignment may be accomplished either by means of a gnomon and local solar noon tables or by magnetic compass and values of local magnetic variation. The Model 141-T ALDF has the capacity to use a GPS receiver system to provide an accurate (±300 nanosecond) timing reference. Since the ALDF Model 141-T has GPS capability, it can also derive its average GPS position, which can then be entered into the system and used in calculating lightning strike locations. The Model 141-T ALDF may be configured either as STANDARD (no GPS) or as GPS. In STANDARD configuration, GPS timing and commands have no meaning for the sensor.

The ALDF has three modes; data mode (normal operating mode), self-test mode and command mode. The sensor cannot detect lightning unless it is in data mode. Each ALDF defaults to data mode once power is applied, after completing a self-test (duration approximately 10 seconds), upon return from command mode or after a specified time-out. The ALDF is designed to operate autonomously to gather lightning data should there be no commands from the central processor (APA). For transmission of data, the ALDF sensors support standard baud rates of 300 to 9600. The current baud rate is set at 4800.

Self-test mode is executed by default on the hour (unless the ALDF is processing lightning data) or on command. Currently, the APA is configured to request a self-test every minute. During the self test, the sensor injects test pulses of known amplitude into windings co-located with the antennas and measures the resulting response. Each self-test requires about 10 seconds to complete. The resulting PASS/FAIL condition from the latest self-test is incorporated into a confidence message which is passed to the APA periodically. Any lightning that occurs while the ALDF is in self-test mode is not processed.

During data mode, whenever a cloud-to-ground lightning flash is detected, the ALDF measures the bearing angle to the ground strike point, the peak signal strength, the time the signal arrived at the sensor, the rise time and width of the signal for all strokes of the flash. This data is encoded and sent to the APA. The encoded flash data consists of time (to nearest millisecond), angle (azimuth), signal strength and number of strokes in the flash (multiplicity). An ALDF encoded confidence message is also transmitted at an interval which can be set by command (default internal is 30 seconds). The confidence (status) message consists of time, self-test pass/fail status, temperature inside the ALDF dome enclosure and ALDF enable threshold. The confidence message is suppressed during transmission of flash data. Flash and status data are sent as 7 bit ASCII characters enclosed by one start bit, one even-parity bit and one stop bit (total of 10 bits). This is the default transmission format for all data but other transmission formats are available via special commands. The encoded data is meant to be used solely by the APA although it can be displayed on any ASCII terminal. The ALDF also has the ability to transmit un-encoded ASCII flash and stroke data for diagnostic purposes, but this data has no meaning to the APA since it is not in the encoded format. It is useful only for printing or display on an ASCII data terminal for test purposes.

In command mode, the ALDF will accept instructions to perform housekeeping functions, run diagnostic programs or report miscellaneous conditions and results. An ALDF may be commanded to change modes or control data output by one of several control sequences.

1.2 ADVANCED POSITION ANALYZER (APA)

The IMPACT Model 283-T Advanced Position Analyzer receives, decodes, correlates and stores the data from each ALDF in the system. It provides the central data processing capability for CGLSS. It can process the information from up to 16 ALDF sensors, but there are only 6 active ALDF sensors currently in the CCAFS/KSC array. The APA accepts data from each of the ALDF sites at baud rates between 300 and 9600 (asynchronous, switch selectable, currently 4800 baud).

A cloud-to-ground lightning flash is typically composed of several individual cloud-to-ground return strokes, each of which transfer charge from the cloud to the ground. Each stroke can have a peak current of up to approximately 300 kiloAmperes with a duration of 20-50 microseconds and typically separated in time by 20-100 milliseconds. The ALDF have sufficient time resolution and sensitivity to detect the individual strokes. For practical purposes, researchers have defined a flash as consisting of all cloud-to-ground discharges which occur within 10 km of each other and within a one second time interval.

The APA analyzes the cloud-to-ground lightning strikes detected by the ALDF sensors, correlates the data to determine the location and amplitude of each stroke, determines number of strokes in each flash and records the data on hard disk. The APA uses two methods to group strokes into flashes; All Stroke Reporting (ASR) and All Stroke Positions (ASP). Under ASR, the sensors send back all stroke data to the APA which correlates the strokes on the basis of time and assigns strokes to flashes on the basis of angle. When using ASP, the strokes are time correlated as before, but grouped into flashes on the basis of time and position (location) rather than angle.

In order to process the ALDF data into flashes, the APA performs a sequence of steps as follows:

1. Receive sensor data into the APA communications controller.
2. Sensor data is placed in a holding buffer with two time stamps, one from the APA and one from the sensor that sent it.
3. The APA generates time correction values for those sensors that do not have GPS clocks.
4. Strokes are correlated by time and angle (or position) information into flashes.
5. The location of the flash is determined according to one of several optimization methods.
6. The flash and stroke data are output according to one of several formats onto reports and stored onto hard disk for later processing. Data may be later downloaded to 5.25” floppy disk for archival storage.

The APA has two printers available for hardcopy output. The Region printer is dot-matrix (Digital Equipment Corp.) and connected to the standard port 10 of the APA. It can output data for lightning strikes which occur within a specified region of latitude and longitude. The System printer is also a dot matrix type (Fujitsu) and is connected to the printer port of the APA. It is used for general system output.

1.3 NETWORK DISPLAY SYSTEM (NDS)

The Network Display System (NDS) equipment is located in Rm. 146 of the ROCC. NDS consists of an IBM-compatible PC running the NDS real-time lighting display software (COTS from GAI) with VGA monitor, keyboard and color inkjet printer (HP Deskjet 660C). The NDS receives flash position information from the APA, checks for transmission errors and proper format, decodes the position information, stores the flashes to disk and plots the flashes on a geographical background map such as that depicted in the sample NDS display shown in Figure -3.

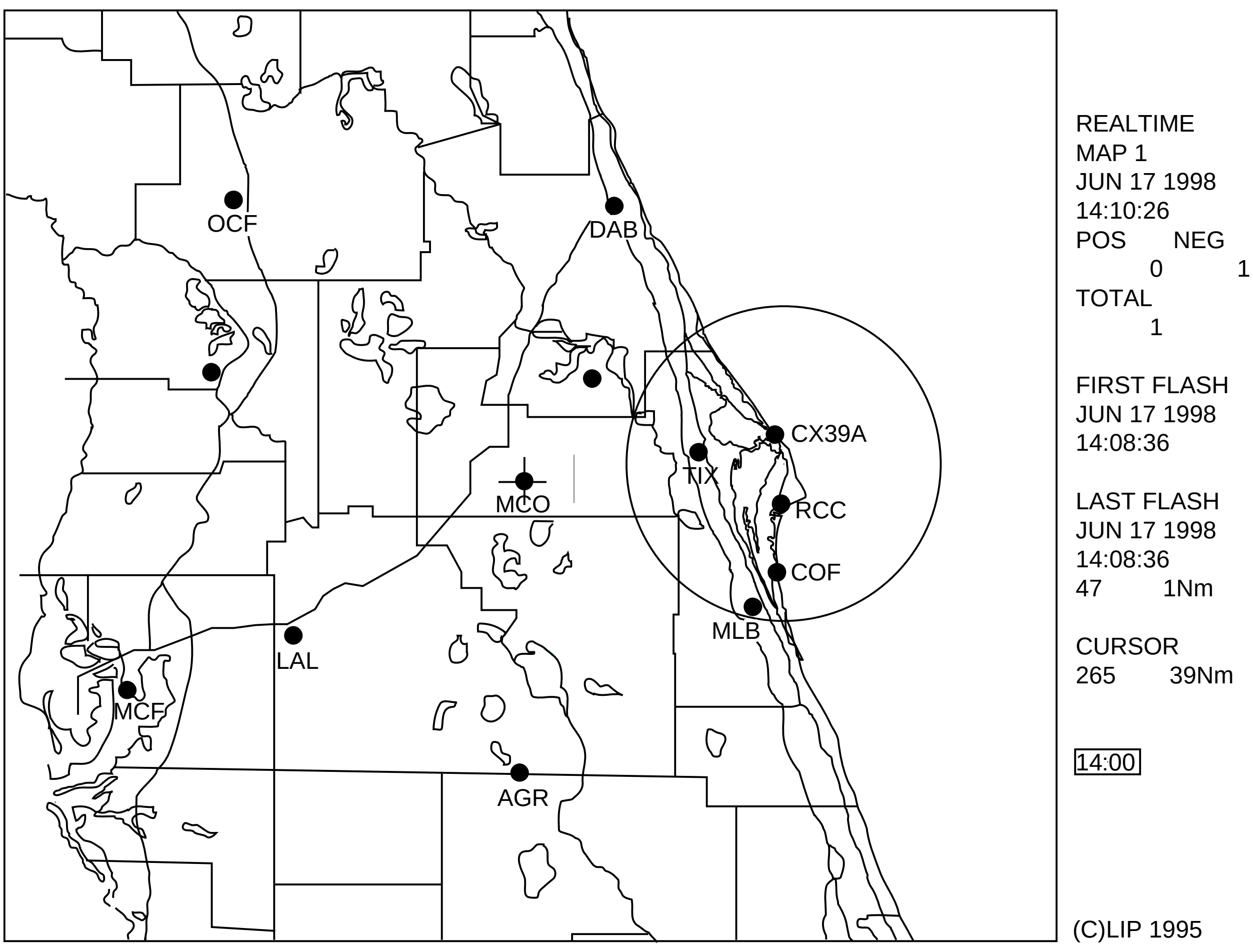

Figure -3. CGLSS NDS Display Sample

2.0 SYSTEM CAPABILITIES

CGLSS collects data from 6 ALDF sites regarding time, strength, direction and multiplicity of cloud-to-ground lightning flashes within 50 nmi of CCAFS/KSC. The range of sensitivity of CGLSS is adjustable via APA commands and hardware settings. Advertised flash detection efficiency is 75% for the nominal range and gain settings. Data are stored to system hard disk for future reprocessing and may be downloaded to 5.25” floppy disks for archiving. The ALDF sensors are automatic and self-starting. The Model 283-T APA is capable of handling up to 16 ALDF sensors.

Location accuracy for cloud-to-ground lightning strikes is a function of many variables, including the number of sensors which detect a lightning strike, distance and strength of the strike, and geometry between the sensors and the strike location. There is no vendor-specified location accuracy for CGLSS as a whole. The measured strike location accuracy is (TBD).

For strikes which are detected by several sensors, the CGLSS APA may use any of several methods to obtain the best estimate of strike location. One method, called baseline optimization by signal strength, adjusts the stroke location and signal strength to minimize the angle (bearing) and signal strength disagreement. This method is used when only two sensors detect the strike on or near the baseline joining them. Another method involves iterative adjustment of stroke position and signal strength to minimize the range and angle disagreement. It is generally referred to as the ‘standard form’ and utilizes triangulation between several pairs of sensors.

Various APA commands provide for control over the IMPACT flash detection and location algorithm. For example, the type of optimization is controlled by specifying a code in the OPT command. Other commands provide control over the signal detection threshold, the processing delay time and sensor site corrections.

3.0 CONCEPT OF OPERATIONS

CGLSS operates 24 hours/day, 7 days/week and provides real-time display of the location, strength and multiplicity of cloud-to-ground lightning flashes for the CCAFS/KSC area in support of ground-based processing and launch operations. Once the ALDF sites are installed, aligned to true north and calibrated, their operation is automatic. If data is interrupted due to power outages, they have the ability to perform an automatic restart using pre-selected (or default) set-up parameters once power is restored. As the ALDF sense cloud-to-ground lightning strikes, they provide the data to the APA which correlates the data from all the ALDF sites for each stroke detected and determine how many strokes occurred for each flash, the resultant flash location and signal strength. Data is stored to hard disk on the APA and may be subsequently downloaded to removable storage media (5.25” floppy disk). The data are available for display in RWO using the NDS graphical display equipment. This display provides the Launch Weather Officer (LWO) and duty forecasters with a graphical situation display of the location and frequency of occurrence of lightning in near-real time for use in making weather forecast decisions and issuance of warnings.

4.0 OPERATIONAL LIMITATIONS

The ALDF sites for the CCAFS/KSC area nominally consist of the ALDF instrument anchored to a small concrete pad within a cleared area at ground level at least 200 feet away from any buildings. For best operation, they should be located as far away from sources of electrical noise as possible. This is important since the ALDF use the detected electric and magnetic field changes induced by lightning to perform their function. AC Power transmission lines, electric motors and generators are all sources of noise and interference and reduce the ALDF ability to detect lightning. Power and signal cables should be buried for the last 100 feet (30.5 m) up to the ALDF instrument.

CGLSS currently has six installed ALDF sites. A minimum of two sites are required to locate and display lightning. Accuracy improves with each additional site used in the processing.

Since the ALDF sites are widely scattered, response time to sensor outages can be longer than one hour. Additionally, the ALDF located at Seminole, Florida, is sometimes flooded during the wet season which limits accessibility to the site.

During high flash rates, baud rate limitations may require the ALDF to drop data. If this occurs, all data associated with a particular flash will be dropped (not recoverable). This means that no partial flash records will be transmitted to the APA under these conditions.

The ALDF are designed to operate in the typical CCAFS/KSC external environment (barring natural disasters). Table -1 provides the operating environment specifications for the GAI Model 141-T ALDF sensors. Since the system was upgraded to the new ALDF sensors there has been an on-going problem with the ILRUs experiencing moisture intrusion due to an inferior gasket design. The technicians must continually change the dessicant to keep the enclosure dry.

Table -1. Operating Environment Specifications for the GAI Model 141-T ALDF sensors.

Environmental Parameter	Operational Specification	Survival Requirement
Temperature	-40 to +120 F (-40 to +50 C)	-80 to +130 F (-62 to +55 C)
Rain	3 in/hr at 35 kt (7.6 cm/hr at 65 km/hr)	5 in/hr at 84 kt (12.7 cm/hr at 155 km/hr)
Humidity	0 to 100%	
Wind	0 to 130 kt (0 to 240 km/hr)	
Ice	3 in Radial Accumulation (7.6 cm)	
Altitude	-1500 to 18000 ft (-450 to 5500 m)	

CGLSS is expected to provide high reliability if the vendor-recommended preventive maintenance procedures are followed. The Model 141-T ALDF have an advertised Mean Time Between Failure (MTBF) exceeding 50,000 hours and a nominal Mean Time To Repair (MTTR) of 30 minutes. The GAI IMPACT 283-T APA has no stated MTBF or MTTR. The APA requires ordinary facilities afforded non-hardened computers. The APA utilizes hard disk, floppy disk and dot matrix printer devices which need a cool, clean environment for proper operation, such as that provided at the ROCC.

Since the upgrade in May of 1998 the system has had a systematic problem of locating and displaying erroneous flashes on the NDS. All attempts by the RTS contractor to correct the problem have failed. GAI has been contacted and data forwarded for their evaluation. To date the cause of this problem has not been identified. On two occasions over 20,000 flashes were archived and forwarded to GAI so that a network evaluation could be performed. Site correction factors were derived from each evaluation and loaded into the system. In both cases the erroneous flashes continued.

5.0 LOGISTICS

The ALDF sites, APA and NDS are maintained for range operations by the RTS contractor. Spares are currently available for the 283-T APA (earlier version 280-T) and the PLRU and ILRU located at the ALDF. There is no spare antenna assembly for the ALDF.